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QUICK PATH SURVIVABILITY FOR MESHED COMMUNICATIONS NETWORKS ;

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ABSTRACT:

For each potential end-to-end connection through a network (118), a plurality of possible communications paths (22, 24, 26, 28) are identified and ranked in order of preference for selection. One of these communications paths is initially selected (112) to support a request (110) for establishment (114) of an end-to-end connection. The remaining possible communications paths comprise alternative communications paths to that selected communications path. In the event of a failure (116) of the selected communications path, one of the pre-defined alternative communcations paths is selected (118) to replace (120) the failed selected communications path and provide continued support of the end-to-end connection. The alternative communications path that is selected most likely comprises that one of the pre-defined paths having a highest relative preference ranking. Consideration may also be given during selection as to whether that highest ranked alternative communications path has sufficient capacity to serve the end-to-end connection.

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(57) Abstract

For each potential end-to-end connection through a network (118), a plurality of possible communications paths (22, 24, 26, 28) are identified and ranked in order of preference for selection. One of these communications paths is initially selected (112) to support a request (110) for establishment (114) of an end-to-end connection. The remaining possible communications paths comprise alternative communications paths to that selected communications path. In the event of a failure (116) of the selected communications path, one of the pre-defined alternative communcations paths is selected (118) to replace (120) the failed selected communications path and provide continued support of the end-to-end connection. The alternative communications path that is selected most likely comprises that one of the pre-defined paths having a highest relative preference ranking. Consideration may also be given during selection as to whether that highest ranked alternative communications path has sufficient capacity to serve the end-to-end connection.

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QUICK PATH SURVIVABILITY FOR MESHED COMMUNICATIONS NETWORKS

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to a communications network and, in particular, to a method and apparatus for responding to communications path failure within such a network by predefining alternative communications paths for subsequent selection and use in the event of a path failure.

Description of Related Art

When a connection is established between two end users through nodes of a transport network, this connection is typically carried through the transport network over a selected communications path (also referred to as a link). It is recognized that in some instances the selected communications path fails. Path failure often results in a termination of the supported end-to-end connection.

To address this problem, the provider of the transport network may provide for some system back-up capabilities through the use of redundant network components that may be quickly switched in to support the end-to-end connection following a detected path failure. This option allows for continued transport network support of the connection in spite of an isolated path failure instance. The use of redundant or back-up network architecture unfortunately increases the cost of the network with additional capacity that often goes wasted during normal operation. What is needed is a more efficient mechanism for continuing to support an established end-to-end connection in the event of a communications path failure.

SUMMARY OF THE INVENTION

In a communications network, a number of possible communications paths exist between any two given nodes within that network. For each possible end-to-end

connection through the network, the plural possible communications paths are identified, ranked in order of preference for selection and stored in a path table. In response to a request for the establishment of an end-to-end connection, one of the communications paths is initially selected to support that connection. The remaining possible communications paths (now comprising alternative paths) comprise potentially available paths to replace the selected communications path in the event of a failure of the selected communications path. Responsive to a detected failure of the selected communications path, the path table is consulted in order to select one of the alternative communications paths. This selection may be made with consideration given to capacity on the alternative communications paths and/or priority rankings assigned to each alternative communications path. More specifically, the highest ranked alternative communications path having sufficient capacity is chosen to replace the failed selected communications path and provide continued support for the end-to-end connection.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be acquired by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

FIGURE 1A is a block diagram of a simple fully meshed communications network incorporating a path survivability feature of the present invention;

FIGURE 1B is a block diagram of a simple partially meshed communications network incorporating the communications path survivability feature of the present invention;

FIGURE 2 is a flow diagram illustrating a process for configuration management tool operation in defining communications paths which support end-to-end connections within a communications network; and

FIGURE 3 is a flow diagram illustrating a process for configuration management tool operation in handling end-to-end connections and potential communications path failure.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is now made to FIGURES 1A and 1B wherein there are shown block diagrams of a simple four node 10, 12, 14 and 16 communications transport network 18. In FIGURE 1A, the transport network 18 is "fully meshed." By this it is meant that a direct communications link 20 exists between each and every node 10, 12, 14 and 16. In FIGURE 1B, on the other hand, the transport network is "partially meshed" because a direct connection does not exist between each and every node (see, for example, the missing direct connection between node 12 and node 14). The communications links 20 interconnecting the nodes 10, 12, 14 and 16 may support any of a number of known transports such as a synchronous optical network (SONET), asynchronous transfer mode (ATM), hybrid fiber coax (HFC), high speed digital subscriber line link (HDSL), T1, T3, Gigabit-LAN, and the like.

It is noted that in such partially or fully meshed communications networks, a number of different communications paths may be defined between any two of the nodes 10, 12, 14 and 16. Take, for example, the end-to-end connection between node 10 and node 12 in the fully meshed network 18 of FIGURE 1A. Possible communications paths supporting this end-to-end connection include: path 1 (reference 22) from node 10 to node 12 directly; path 2 (reference 24) from node 10 to node 12 through node 14; path 3 (reference 26) from node 10 to node 12 through node 16; and, path 4 (reference 28) from node 10 to node 12 through nodes 14 and 16. Similarly, in the partially meshed network 18 of FIGURE 1B, possible communications paths for end-to-end connection between node 10 and node 12 include: path 1 (reference 22) from node 10 to node 12 directly; path 3 (reference 26) from node 10 to node 12 through node 16; and, path 4 (reference 28) from node 10 to

node 12 through nodes 14 and 16. A number of other paths similarly exist and can be defined between the other nodes 10, 12, 14 and 16 of the network 18.

The network 18 includes a transport network management system (TNMS) 30. The transport network management system 30 manages operation of the network 18 by providing conventional, well known, functionality for fault management. The transport network management system 30 further functions in accordance with a configuration management tool (CMT) 32 which supports the path survivability feature of the present invention to identify and pre-define each of the plural possible communications paths which are available for use in establishing an end-to-end connection between each of the plurality of nodes 10, 12, 14 and 16 of the network 18. More specifically, the configuration management tool 32 polls the network 18 to identify each of its included nodes 10, 12, 14 and 16, as well as the communications links 20 interconnecting those nodes. With this node and link information, the configuration management tool 32 can determine and make record of each of the available communications paths. The configuration management tool 32 further ranks the plurality of communications paths in order of preference for use in supporting an end-to-end connection between each of the nodes. Factors affecting the priority ranking of each path include: number of intermediate nodes implicated by the path; congestion on the communications link(s) making up each path; congestion in each node along the path; cost associated with the path; and the like. As an example, again returning to the end-to-end connection between node 10 and node 12 in the fully meshed network 18 of FIGURE 1A, each of the communications paths between node 10 and node 12 are identified and pre-defined, and further the paths are ranked from path 1 to path 4 in order of preference for selection with path 1 having a highest relative priority ranking, and path 4 having a lowest relative priority ranking.

The communications paths are defined by the configuration management tool 32 with respect to each of the end nodes using a nomenclature of n.x/y wherein n refers to the path number (and its relative priority ranking with respect to the plural

alternative paths potentially supporting the same end-to-end connection), x refers to a circuit within that path, and y refers to a sub-channel. In this regard, x may identify a particular port (i.e., circuit) at a node in the network through which the communications path passes. The purpose of the port identification is to associate a virtual path connection through the network with a physical entity at the node. Furthermore, y may refer to a selected end device (i.e., sub-channel) connected to the end node. Thus, the purpose of the end device identification is to associate the physical connection at the node with a particular device.

The foregoing may be better understood by reference to a specific example. With reference once again to FIGURE 1A or 1B, and more particularly for example to path 3 therein, it is assumed path 3 supports an end-to-end connection between a certain first device (device#1) connected to node 10 at port 2A, and a certain second device (device#2) connected to node 12 at port 3B (through node 16. This communications path may accordingly be defined at end node 10 as follows: path#3.port2A/device#1, and may similarly be defined at end node 12 as follows: path#3.port3B/device#2. A pass through node identification for the path may also be defined as follows: N4 (BW), wherein BW refers to the amount of bandwidth reserved at the node for pass through path use. This pass through node designation is bound to the end node designations by the configuration management tool 32. Alternative paths to path 3 may be found by looking for path identifications that have the identical x and y designations at each end node. Thus, an alternative path to path 3 would comprise path 1 which is defined with identical x and y designations at end node 10 as follows: path#1.port2A/device#1, and may similarly be defined with identical x and y designations at end node 12 as follows: path#1.port3B/device#2. I this instance it is noted that there is no pass through node designation for this path. The n designation for the paths further identifies relative priority rankings with respect to the plural alternative paths potentially supporting the same end-to-end connection. Thus, path 1 has a higher priority ranking than path 3.

The pass through node designations are identified by the configuration management tool 32 when polling the network, and are then utilized during path definition to form binding between the n.x/y designations of the end nodes and the N# (BW) designation of the intermediate nodes along the defined path. A portion of the available bandwidth at each node is reserved for use by path through paths (as opposed to end node connections). This reserved bandwidth is then partitioned and assigned out to defined pass through paths. When the reserved bandwidth runs out during the definition and binding process, that node is no longer available to the configuration management tool 32 for binding into a path as a pass through node.

The transport network management system 30 in general operates to monitor network 18 operation and more specifically in the context of the present invention operates to monitor the network 18 for communications path failure. Failure may be caused by a loss of the path or communications link 20, or an excessive bit error rate on the path. If such a failure is detected, it is reported to the configuration management tool 32. The configuration management tool 32 responds to the reported failure of a selected communications path by selecting an alternate one of the plurality of pre-defined communications paths that exist between the nodes at issue. This selection is made with consideration given to the availability of each alternative communications path and the priority ranking assigned to each alternative communications path. The configuration management tool 32 normally selects the highest ranking one of the available alternative communications paths. Availability turns, for example, on whether the communications path has, at the time of path failure, sufficient capacity to support the end-to-end connection that existed between the nodes in the failed communications path. Thus, as an example, if the serving communications path is identified by the nomenclature n1.x1/y1, the most likely to be chosen alternative path in the event of a path failure would be that path found in the path table and identified by the nomenclature n2.x1/y1.

Each node 10, 12, 14 and 16 of the network 18 includes a path handler (PH) functionality 34. This functionality 34, in general, operates from end node to end node to establish and tear down communications paths in order to support the end-to-end connections. More specifically, in the context of the present invention, the path handler functionality 34 operates from end node to end node responsive to instructions received from the configuration management tool 32 to establish the selected communications path for supporting an end-to-end connection, and also to establish, in the event of a failure of the selected communications path, the alternative communications path for continued support of the end-to-end connection. The instructions issued by the configuration management tool 32 are sent to the path handler functionalities for nodes implicated in both the failed selected communications path and the to be substituted alternative communications path in hierarchical order. This order is specified to correspond with an alphabetic code designation assigned to the node and its path handlers. Referring again to the n.x/y designation for the example path 3 discussed above, node 10 has an "A" alphabetic code designation and node 12 have a "B" alphabetic code designation. Thus, the configuration management tool 32 issues any instructions to the path handlers 34 by first sending the instructions to node 10 (designated A) and then sending the instructions to node 12 (designated B).

Reference is now made to FIGURE 2 wherein there is shown a flow diagram illustrating a process for configuration management tool operation in defining communications paths which support end-to-end connections within a communications network. In step 100, the configuration management tool polls the network (using simple network management protocol SNMP or the like protocol) to collect topology information relating to the identity each of its included nodes and how those identified nodes are interconnected by communications links. From this collected information, the configuration management tool next identifies in step 102 those nodes that could possibly comprise end nodes in supporting an end-to-end connection. The configuration management tool further processes the collected

information in step 104 to identify those nodes that could possibly comprise pass-through nodes in an end-to-end connection between the step 102 identified end nodes. Available and reserved bandwidth information is also noted. The end node and pass-through node identifications, as well as the bandwidth information, are then processed in step 106 to build a path table identifying for each pair of identified end nodes the plurality of available communications paths that may be established (either directly or via a pass-through node) to support an end-to-end connection. In this manner, the n.x/y designations for each end node and pass through node number (binding) relating to each possible communications path are pre-defined in the path table for purpose of identifying the plural alternative paths potentially supporting the same end-to-end connection. Priorities among and between the plural alternative paths potentially supporting the same end-to-end connection are also determined and noted in the path table (by the assignment of the n identification in the n.x/y nomenclature) for future reference and consideration is selecting between the plural alternative paths at both initial set-up of the path and in the event of a path failure and alternative path selection. The process of steps 100, 102, 104 and 106 may be performed on a periodic basis such that the path table is updated on a regular basis to account for node and communications link additions and deletions to the network.

Reference is now made to FIGURE 3 wherein there is shown a flow diagram illustrating a process for handling end-to-end connections and potential communications path failures. In step 110, a request in made for the establishment of an end-to-end connection between two end nodes. Responsive to the request, the path table is consulted in step 112 to select a preferred one of the plurality of suitable communications paths to support the requested end-to-end connection (most likely the n1 identified path). The requested end-to-end connection is then established over that selected communications path in step 114. It is recognized at this point that each of the remaining communications paths identified in the path table which could support the requested end-to-end connection between those end nodes now comprise

alternative communications paths to that selected communications path. The process next monitors in step 116, through the efforts of the transport network management system, for a failure of the selected communications path. If a failure is detected, the path table is consulted in step 118 to select one of the alternative communications paths (for example, the n2 identified path) to provide continued support for the end-to-end connection. The selection decision of step 118 may take into consideration any number of factors including, for example, the availability of each alternative communications path (i.e., is it free and does it have sufficient capacity), and the priority ranking assigned to each alternative communications path. The end-to-end connection is then switched over to that selected alternative communications path in step 120. This switching process is initiated by sending (in order according to alphabetic designation) appropriate instructions from the configuration management tool to the path handler functionalities at each implicated end node. If no failure is detected in step 116, or if a path switch has occurred in step 120, the process next checks in step 122 to determine whether the currently being supported end-to-end connection has been user terminated. If not, the process returns to the monitoring action of step 116. If yes in step 122, the communications path supporting that end-to-end connection is released in step 124. The process illustrated in FIGURE 3 may be executed either separate from, or alternatively within, the process illustrated in FIGURE 2.

Although preferred embodiments of the method and apparatus of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

WHAT IS CLAIMED IS:

1. A communications network, comprising:

a plurality of interconnected nodes defining a plurality of possible communications paths that are capable of supporting a certain end-to-end connection through the network;

a transport network management system operable to monitor network operation and identify instances of communications path failure; and

a configuration management tool for:

storing a path table that identifies the plurality of possible communications paths supporting that certain end-to-end connection;

selecting from the stored path table, in response to transport network management system detection of the failure of a certain one of the communications paths selected to support that certain end-to-end connection, an alternative one of the communications paths capable of supporting that certain end-to-end connection; and

instructing the nodes of the communications network to switch the certain end-to-end connection from the failed certain one of the communications paths to the selected alternative one of the communications paths.

2. The communications network as in claim 1 wherein the path table pre-defines in a ranked priority for selection the plurality of possible communications paths supporting the certain end-to-end connection, and the configuration management tool selection of the alternative one of the communications paths capable of supporting that certain end-to-end connection comprises selecting the alternative one of the communications paths capable of supporting that certain end-to-end connection having a highest ranked priority in the path table.

3. The communications network as in claim 1 wherein each communications path is specified with respect to each end node within the network by a circuit utilized within that communications path at that end node and a sub-channel utilized for that communications path at that end node.

4. The communications network as in claim 3 wherein each of the communications paths supporting the certain end-to-end connection have a different path identification and identical circuit and sub-channel specifications.

5. The communications network as in claim 1 wherein each communications path is specified with respect to each end node within the network by a port utilized by that communications path at the end node and an end device utilizing that communications path and connected to the port at the end node.

6. The communications network as in claim 5 wherein each of the communications paths supporting the certain end-to-end connection have a different path identification and identical port and end device specifications.

7. In a communications network comprising a plurality of interconnected nodes defining a plurality of possible communications paths that are capable of supporting a certain end-to-end connection through the network, a method for responding to communications path failure, comprising the steps of:

storing an identification of the plurality of possible communications paths supporting that certain end-to-end connection;

monitoring network operation to identify instances of communications path failure

selecting, in response to detection of the failure of a certain one of the communications paths selected to support that certain end-to-end connection, an

alternative one of the communications paths capable of supporting that certain end-to-end connection; and

instructing the nodes of the communications network to switch the certain end-to-end connection from the failed certain one of the communications paths to the selected alternative one of the communications paths.

8. The method as in claim 7 wherein:

the step of storing further comprises the step of pre-defining a ranked priority for selection the plurality of possible communications paths supporting the certain end-to-end connection; and

the step of selecting the alternative one of the communications paths capable of supporting that certain end-to-end connection comprises the step of selecting the alternative one of the communications paths capable of supporting that certain end-to-end connection having a highest ranked priority.

9. The method as in claim 7 wherein the step of storing further comprises the step of specifying each communications path with respect to each end node within the network with a circuit utilized within that communications path at that end node and a sub-channel utilized for that communications path at that end node.

10. The method as in claim 9 wherein each of the communications paths supporting the certain end-to-end connection have a different path identification and identical circuit and sub-channel specifications.

11. The method as in claim 7 wherein the step of storing further comprises the step of specifying each communications path with respect to each end node within the network with a port utilized by that communications path at the end node and an

end device utilizing that communications path and connected to the port at the end node.

12. The method as in claim 11 wherein each of the communications paths supporting a given end-to-end connection have a different path identification and identical port and end device specifications.

13. In a communications network comprising a plurality of interconnected nodes defining a plurality of possible communications paths that are capable of supporting a certain end-to-end connection through the network, a path management functionality, comprising:

a path handler for each node operable responsive to a received configuration request for providing configuration data relating to that node's capability to function as an end node and/or pass through node; and

a configuration management tool operable for sending configuration requests to each node and processing responsive configuration data received from the nodes to define plural redundant paths through the network between end nodes.

14. The functionality of claim 13 wherein the configuration data includes information concerning an amount of bandwidth reserved by each node for pass through use, and wherein the configuration management tool defines the plural redundant paths to accommodate each node's reserved pass through bandwidth.

15. The functionality of claim 13 wherein the configuration management tool responds to a detected instance of communications path failure by selecting an alternative redundant communications path and instructing the nodes to switch an end-to-end connection from the failed communications path to the alternative communications path.

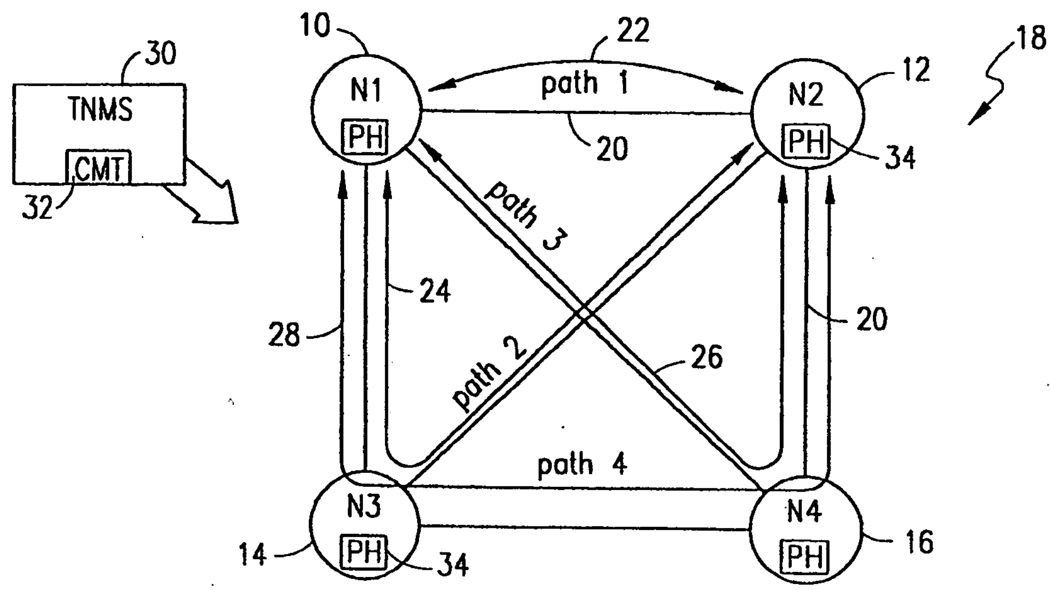
TNMS
CMT
30
32
10
N1
PH
22
path 1
20
N2
PH
12
34
18
path 3
path 2
24
28
26
20
path 4
N3
PH
14
34
N4
PH
16

FIG. 1A

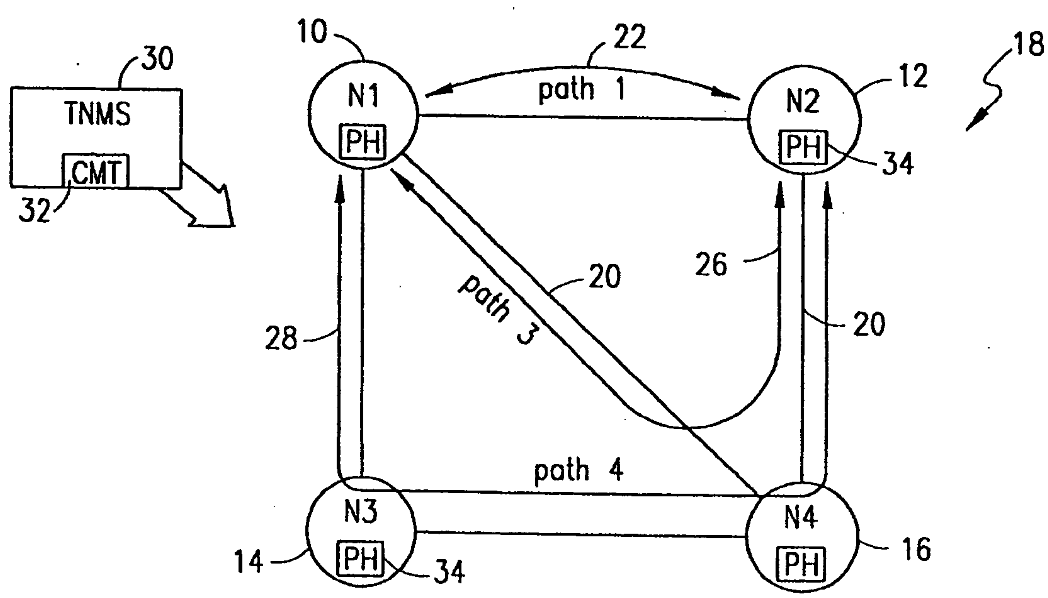
TNMS
CMT
30
32
10
N1
PH
22
path 1
N2
PH
12
34
18
path 3
20
26
20
28
path 4
N3
PH
14
34
N4
PH
16

FIG. 1B

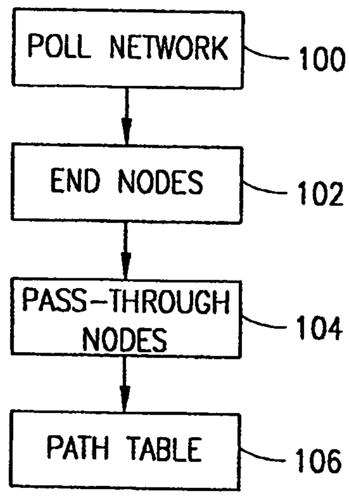
POLL NETWORK
100
END NODES
102
PASS-THROUGH NODES
104
PATH TABLE
106

FIG. 2

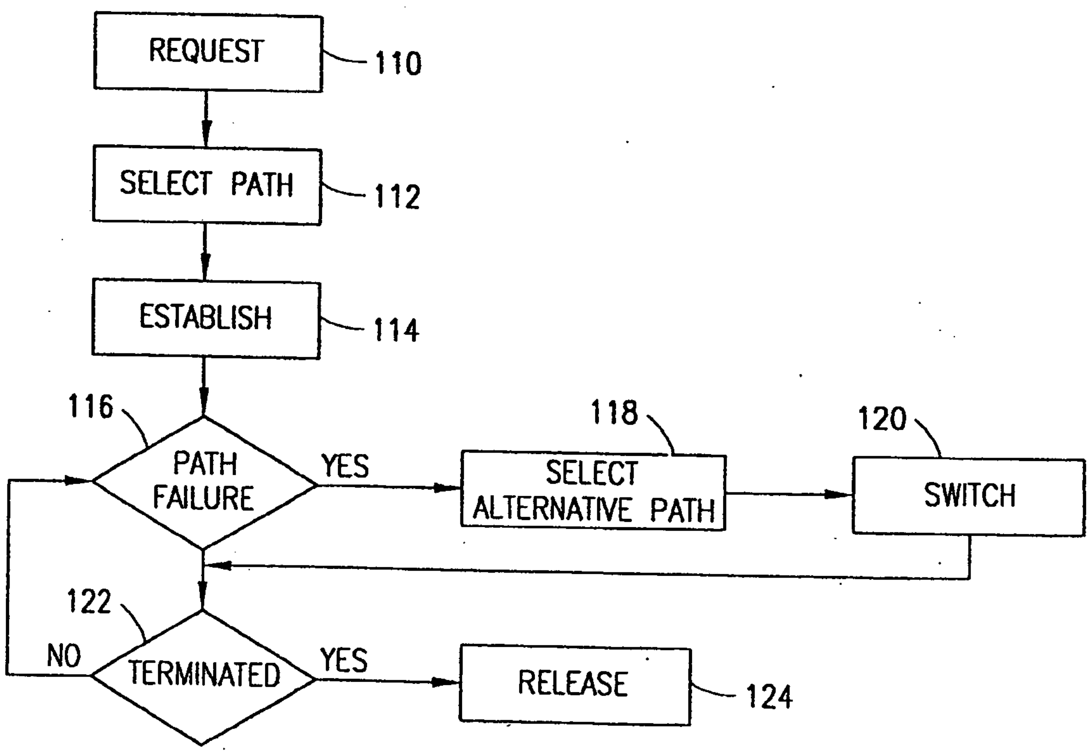
REQUEST
110
SELECT PATH
112
ESTABLISH
114
116
PATH FAILURE
YES
118
SELECT ALTERNATIVE PATH
120
SWITCH
122
NO
TERMINATED
YES
RELEASE
124

FIG. 3